North American Journal of Aquaculture 61:64–69, 1999
American Fisheries Society 1999

Wading Bird Predation at Tropical Aquaculture Facilities in Central Florida

MICHAEL L. AVERY,* DAVID S. EISELMAN,[1] MARK K. YOUNG,[2]
JOHN S. HUMPHREY, AND DAVID G. DECKER

U.S. Department of Agriculture, National Wildlife Research Center, Florida Field Station, 2820 East University Avenue, Gainesville, Florida 32641, USA

Abstract.—In 1995 and 1996, fish loss due to bird predation was documented at 18 ponds at seven aquaculture facilities in central Florida. Losses in ponds from which birds were excluded with netting averaged 11.1%, whereas losses in unnetted ponds averaged 37.6%. Populations of wading birds varied among facilities, but the snowy egret *Egretta thula,* green-backed heron *Butorides striatus,* tricolored heron *E. tricolor,* and little blue heron *E. caerulea* were the principal depredating species. Field observations revealed feeding rates by little blue herons as high as 4 fish/min. Estimated monetary losses at unnetted study ponds averaged US$1,360/pond compared with average losses of $589 at netted ponds. Currently, exclusion is the only technique that is consistently reliable, and it appears that netting ponds to control bird depredations is economically feasible, particularly with high-value fish.

The total value of aquaculture sales in Florida increased from US$35 million in 1987 to $79 million in 1995. With sales of $52.5 million in 1995, tropical fish are the most important component economically of Florida's aquaculture industry. Various species of egrets and herons are the major avian predators at the 205 commercial tropical fish operations in Florida. Although the economic impact of these birds on tropical fish production has never been quantified, producers have stated that depredations by wading birds, if unchecked, would put many of them out of business.

Several factors may contribute to the conflict between wading birds and tropical fish production in Florida. The industry is based east of Tampa Bay, within 50 km of large breeding and wintering populations of wading birds. Tropical fish are grown in small (approximately 8-m × 30-m) outdoor ponds on farms averaging about 5 ha. Ponds are stocked at densities as high as 40,000 fish/pond. Tropical fish are a high-value crop, and one small pond can hold a crop valued at several thousand dollars.

Lethal control of wading birds is not an acceptable option. Public sentiment and local resource management agencies are opposed to such an approach (F. Montalbano, Florida Game and Fresh Water Fish Commission, personal communication). Nonlethal management options (e.g., electric fencing, perimeter netting, distress calls) have been evaluated in other aquaculture situations (Mott and Flynt 1995; Stickley et al. 1995; Andelt and Hopper 1996; Andelt et al. 1997), but the cost-effectiveness of such techniques at tropical fish operations is not known. This study represents the first step in defining the extent and nature of the bird depredation problem at tropical fish facilities. Our objectives were (1) to quantify the losses due to wading bird depredation at tropical fish facilities, (2) to determine the cost-effectiveness of netting as a nonlethal bird management technique, and (3) to quantify wading bird populations and feeding activity at tropical fish farms.

Methods

We identified four commercial operations for study in 1995 and five facilities for study in 1996; two facilities participated in both years. At each commercial operation, we selected two sets of ponds (one to three ponds/set). One set of ponds, chosen by a coin flip, was netted to exclude birds. The second set of ponds, identical in other respects, was not netted and was managed by the pond operator for bird control according to the practices usual for that facility.

We installed nets (black polypropylene, woven 2.5-cm mesh; J. A. Cissel Manufacturing Co., Lakewood, New Jersey) on designated ponds as soon as the ponds were stocked. Nets were supported by three wires strung along the length of the pond and six wires that went across the pond. The support wires were attached by turnbuckles to metal stakes driven into the ground. This permitted the wires to be tightened so that they supported the net without it sagging into the water. At ground

* Corresponding author: dwrc-ffs@afn.org
[1] Present address: University of Florida, Gainesville, Florida 32611, USA.
[2] Present address: Utah State University, Logan, Utah 84322, USA.

Received January 30, 1998 Accepted May 28, 1998

TABLE 1.—Yields from aquaculture ponds at facilities in central Florida. Netted ponds were protected from bird predation by nets suspended across the ponds. Otherwise, netted and open ponds at a given facility were managed identically.

Year and facility	Fish	Study period	Pairs of ponds	Fish per pond	Yield/pond		Loss/pond (%)		Loss/pond ($)	
					Netted	Open	Netted	Open	Netted	Open
1995										
A	Freshwater angelfish *Pterophyllum scalare*	Apr–Jul	3	4,000	3,800	2,300	5.0	42.5	150	1,275
B	Southern platyfish *Xiphophorus maculatus*	Jun–Aug	2	6,000	5,100	3,200	15.0	46.7	135	420
C	Black neon tetra *Hyphessobrycon herbertaxelrod*	Jun–Oct	1	40,000	35,700	37,500	10.8	6.3	645	375
	Black phantom tetra *Megalamphodus megalopterus*	Jun–Oct	1	14,000	11,700	13,000	16.4	7.1	575	250
D	Guppy *Poecilia reticulata*	May–Oct	1	2,500	3,720	1,740	−48.8[a]	30.4	−244	152
1996										
A	Freshwater angelfish	Jul–Oct	1	3,500	2,700	3,000	22.9	14.3	600	375
B	Pink kissing gourami *Helostoma temmincki*	May–Oct	1	5,000	4,800	2,450	4.0	57.0	40	510
	Southern platyfish	Jun–Aug	1	6,000	5,000	4,500	16.7	25.0	150	225
E	Tiger barb *Puntius tetrazona*	May–Sep	2	13,000	12,000	10,300	7.7	20.8	230	621
	Albino tiger barb	Aug–Oct	1	10,000	8,750	1,830	12.5	81.7	325	2,124
F	Cichlids[b]	Apr–Oct	1	3,000	2,911	1,865	3.0	37.8	445	5,675
G	Albino rainbow shark *Epalzeorhynchos erythrurus*	May–Sep	1	1,500	1,446	967	3.6	35.5	68	667
	Plecos *Hypostomus* spp.	Jun–Dec	2	30,000	7,300	4,900	75.6	83.7	4,540	5,020

[a] Number of fish harvested increased over the number stocked because of reproduction during the study period.
[b] Four varieties of cichlid (750 each) were stocked in one pond: *Melanochromis auratus, M. chipokae, Haplochromis venustus,* and *H. redempress.*

level, we secured the edges of the nets with metal pins pushed into the ground to eliminate potential access under the net.

The primary response variable we examined was yield per pond. Thus, we compared the number of fish harvested from netted ponds with no bird predation to the number harvested from open ponds that the owners managed for bird control. We reasoned that if all other factors were equal, a difference in yields between netted and unnetted ponds would be directly attributable to bird predation. The results from netted ponds also provided a measure of fish mortality due to disease, poor water quality, or predators other than birds, such as snakes and insects.

We compared yields between netted and unnetted ponds in a one-tailed paired t-test (Steel and Torrie 1980). Our null hypothesis was that the number of fish harvested from netted ponds exceeded that from ponds without nets. Using information provided by the producers on the value of various types of fish, we calculated the economic loss in the study ponds and compared this between netted and open ponds in another one-tailed paired t-test.

We regularly recorded numbers of birds at each facility from a stationary vehicle. Observations were made during 3-h periods in the morning, afternoon, and evening, and the schedule was arranged so that we visited each facility at least twice weekly. Numbers of individuals of each species were tallied every 15 min. Observations of foraging birds were made from an elevated blind at one facility and opportunistically elsewhere. We observed birds through binoculars and recorded the number of attempts and captures for the duration of the bird's feeding activity at that pond.

Results

Yields from Netted and Open Ponds

With few exceptions, yields from netted ponds significantly exceeded (t = 2.25, df = 11, P = 0.022) those from paired, open ponds (Table 1). At facility D in 1995, yields from the guppy ponds represent two generations because these fish are live-bearers. The netted pond produced almost 50% more fish than were originally stocked, while there was a 30% loss in the open pond.

Across all 13 sets of ponds, losses from netted ponds averaged 11.1% (SE = 7.2), whereas losses from open ponds averaged 37.6% (SE = 6.9). Certain varieties, because of appearance or behavior, were evidently particularly prone to bird predation. These include pink kissing gourami, albino rainbow sharks (=rainbow sharkminnows *E. frenatum*), albino tiger barbs, and some cichlid varieties. Four types of cichlids, 750 each, were stocked together. The two brightly colored varieties, *Haplochromis redempress* and *Melanochromis auratus,* were preyed upon to a much greater extent than were the other two varieties, *M. chipokae* and *H. venustus,* both of which are mottled and darkly colored (M. Tanner, Aquatica, personal communication).

In 1996, almost twice the numbers of pink kissing gourami were harvested from the netted pond than from the open ponds at facility B (Table 1). The fish harvested from the open ponds, however, tended to be larger (P. Norton, Norton's Tampa Bay Fisheries, personal communication), and thus many were sold at a higher price ($0.30/fish) than the smaller fish ($0.20/fish).

Estimated economic losses differed significantly (t = 1.91, df = 11, P = 0.040) between netted and open ponds (Table 1). Mean loss from open ponds was $1,361 (SE = $514) compared with $589 (SE = $337) from netted ponds, for an average difference of $772 (SE = $405). The greatest difference, $5,230, was from the cichlid ponds at facility F (Table 1), where each fish was worth $5.00 (Tanner, personal communication). On the other hand, at facility C in 1995 and at facility A in 1996, estimated losses were actually slightly higher in netted ponds (Table 1).

Surveys of Piscivorous Bird Species

Seven species of wading birds were commonly observed throughout the study facilities: great blue heron *Ardea herodias,* snowy egret *Egretta thula,* great egret *Casmerodius albus,* green-backed heron *Butorides striatus,* little blue heron *E. caerulea,* tricolored heron *E. tricolor,* and black-crowned night-heron *Nycticorax nycticorax.* Populations of wading birds varied among facilities, but mean numbers generally were within a range of one to four birds per 15-min count period (Figure 1). At facility B, numbers of wading birds peaked in July 1995 and then declined to very low levels by the end of the study.

The relative abundance of wading bird species varied among facilities, but in general during 1995, the snowy egret was the most abundant species. Surprisingly, the next most common species was the green-backed heron. This was not one of the species identified initially as a major aquaculture pest, but it frequented most of the study facilities and was the most abundant species at study facility B during 6 of the 9 months surveyed. In 1996, the green-backed heron again was very common at facility B but was rarely found at facilities E and G, where the great egret and snowy egret were predominant. The snowy egret was the most common species observed at facility A, while the tricolored heron was the most common species at facility F.

Observations of Depredating Birds

We obtained several observations of wading birds actively preying on fish, and therefore, we were able to obtain estimates of feeding rates and capture success. On two occasions, little blue herons were observed for 5 min taking fish. One bird captured five southern platyfish without a miss, whereas the other bird caught 20 fish (variety undetermined) and missed twice. The other six occasions all involved tricolored herons (Table 2).

Discussion

Many factors affect the number of fish produced from a given pond. For example, the 1996 data from ponds containing plecos at facility G were exceptional because of very high losses from the netted ponds. Apparently, pleco production was depressed in general throughout the region, probably due to stock that was less vigorous than normal (Norton, personal communication; C. Watts, Watts Aquatic and Zoological, personal communication).

Among the factors relevant to fish losses,, bird predation is often paramount. While estimated monetary losses vary among facilities, it is obvious that at least some tropical fish producers incur considerable bird depredations (Table 1). Although concerted use of an auditory scare device at facility B might have contributed to the observed reduction in bird numbers there (Figure 1), at this time, exclusion appears to be the only consistently effective management tactic for controlling wading bird depredations (Curtis et al. 1996). Variation in the species composition of piscivorous wading birds among locations, such as documented in this study (Table 3), suggests that if a species-specific bird deterrent, such as an auditory scare device, is

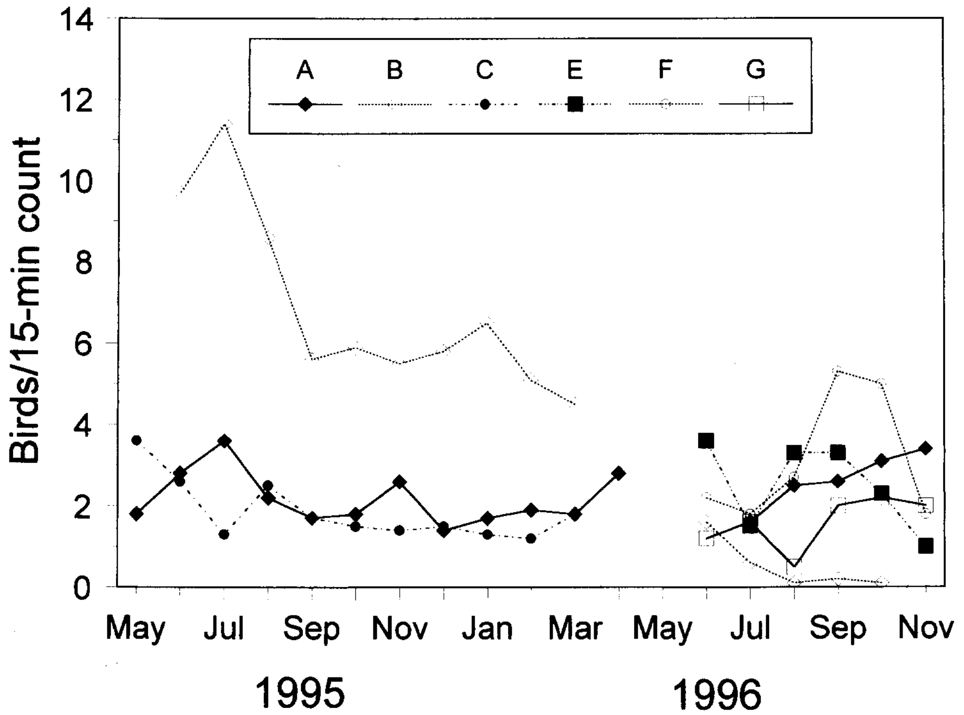

FIGURE 1.—Numbers of wading birds recorded at central Florida tropical aquaculture facilities (A–G) from May 1995 to November 1996.

employed, it must be designed for the species expected to occur at the given facility. Alternatively, a technique such as exclusion with bird netting that is effective against all species can be employed without regard to the species composition at any one location.

Costs related to netting a pond can vary considerably. The materials that we used to exclude birds from our test ponds cost approximately $300/pond. Even though our netting scheme was relatively inexpensive, it may not be practical or convenient for many facilities. Installation of netting over existing structures that support plastic covers for cold protection seems to be one approach that merits consideration. Standard 17-m × 50-m nets can be purchased from various sources for less than $350, depending on the mesh size and net material. This net size should easily cover most tropical fish ponds, particularly when supported by low-profile metal trusses. Although the installation of the net support system can be costly if prefabricated metal trusses are used ($600 to $1,100/pond; C. A. Watson, University of Florida, personal communication), a less costly alternative is

TABLE 2.—Feeding activity of tricolored herons at tropical aquaculture facilities in central Florida in 1996.

Date	Fish	Number of		Duration (min)
		Attempts	Captures	
22 Oct	Variable platyfish *Xiphophorus variatus*	12	7	15.75
22 Oct	Glassfish *Parambassis ranga*	9	6	23.83
24 Oct	Glassfish	1	0	8.00
12 Nov	Southern platyfish	1	1	6.25
12 Nov	Glassfish	3	3	4.33
3 Dec	Southern platyfish	8	6	5.83
Mean all dates		5.7	3.8	10.67

TABLE 3.—Relative abundance of seven species of wading birds at tropical aquaculture facilities in central Florida, May–December 1995 and 1996; GBHE = great blue heron, GREG = great egret, SNEG = snowy egret, LBHE = little blue heron, GNHE = green-backed heron, BCNH = black-crowned night-heron, TRHE = tricolored heron.

Facility	Year	Relative abundance (% of total observations)							Total number
		GBHE	GREG	SNEG	LBHE	GRHE	TRHE	BCNH	
A	1995	5.3	7.6	22.7	6.8	26.3	26.2	5.0	1,376
	1996	6.6	11.2	16.2	21.7	10.8	32.5	0.9	667
B	1995	0.8	5.4	43.4	3.9	42.4	2.9	1.1	3,111
	1996	0.5	5.8	19.9	9.9	63.9	0	0	191
C	1995	3.8	7.5	32.1	0	56.7	0	0	53
D	1995	11.3	45.9	24.1	0	13.5	0	5.3	133
E	1996	3.4	60.4	24.5	11.1	0	0.1	0	1,876
F	1996	6.4	20.1	38.2	15.0	18.3	2.0	0	715
G	1996	4.5	39.3	32.0	20.3	0.4	1.9	1.5	463
Mean		4.7	22.6	28.1	9.9	25.8	7.3	1.0	

to support the net on sturdy wooden poles laid across the pond. Regardless of the support system used, the dual benefits of cold protection and netting for bird control should make the investment worthwhile, particularly because the support structure will last many years.

Even when the cost of netting is not immediately offset by increased fish yields, cost-effectiveness will become evident within several production cycles. For example, in 1996 the difference in yield between netted and open ponds of southern platyfish ($0.15/fish; Norton, personal communication) amounted to $75 at facility B. Installation of a $350 net would be cost-effective after five production cycles.

After a support system is in place, it can become a liability if netting is not used to exclude birds. This is because the support structures provide excellent perches for wading birds and probably encourage differential use of ponds where such structures are present. Thus, we suspect that ponds with supports for cold protection plastic covers that are not netted suffer greater predation losses than ponds without such perching opportunities. We hypothesize that the availability of perches in the form of pond cover supports encouraged the large numbers of green-backed herons present at facilities A and B. This species was notably scarce at facilities E and G, where such pond cover supports were not used.

Even when netting is not deemed feasible, there are certain measures to consider that might reduce the magnitude of losses of fish to wading birds. Great blue herons and other species tend to stay away from human activity (Pitt and Conover 1996), so pond stocking should be planned so that particularly valuable or vulnerable fish are put into ponds closest to the most human activity. Vulnerable fish are those that are brightly colored or that spend a lot of time near the surface. Birds may also prefer densely stocked ponds to those with fewer fish, so lower stocking rates may be worth considering. Reduced density of fish may also produce larger individuals. In 1996, this apparently occurred at facility B, where fewer, but larger, fish were harvested from the open pond relative to the netted pond. Although the increased value of the larger fish in the open pond did not completely make up for the reduction in yield, in some cases, compensatory growth can at least partially offset the effects of bird depredations.

Research Needs

The food habits of the various depredating piscivorous bird species are still not well characterized. Food collections from nestlings at rookeries in the Tampa Bay area (Rodgers 1982), as well as gut contents of birds collected at aquaculture ponds, will further understanding of the importance of tropical fish in the overall diet of the various depredating species. Additional behavioral observations of birds feeding in aquaculture ponds are needed so that the economic impact of predation can be more completely quantified. Daily activity budgets and population size coupled with feeding rates of individual birds will allow calculation of daily predation rates at a given facility, which in turn will yield estimates of economic loss. Such an approach will corroborate estimates already obtained by comparing yields of netted and unnetted ponds.

Alternative damage prevention methods need to be evaluated. Exclusion by using netting is one category of control method, but various approaches to netting can be used, and the cost-effectiveness and feasibility of these options need to be addressed. Other approaches to predation management such as the application of aversive conditioning need to be evaluated. For example it might be possible to treat newly killed fish with an emetic chemical such as methiocarb (Rogers 1974) and place these treated fish in or beside a pond where a piscivorous wading bird might encounter them. The bird that ate the treated fish would then become sick and develop an aversive response to feeding there. Such methods of behavior modification have been applied successfully to other wildlife management problems (e.g., Avery et al. 1995) and might be useful in aquaculture.

An ongoing concern is the possibility that wading birds are responsible for important deleterious effects other than predation. In particular, the role that birds play in the spread of diseases and parasites needs to be understood more fully. Herons can be vectors of viruses (Peters and Neukirch 1986), but the extent to which that occurs and implications of such transmissions for tropical aquaculture are not known.

Acknowledgments

We appreciate the support and advice of C. A. Watson throughout this endeavor. We are grateful for the cooperation we received from aquaculture producers R. Hammar, C. Hukle, P. Norton, H. Simmons, M. Tanner, and C. Watts. We also thank T. Carpenter for field assistance and J. Glahn for review comments.

References

Andelt, W. F., and S. N. Hopper. 1996. Effectiveness of alarm-distress calls for frightening herons from a fish rearing facility. Progressive Fish-Culturist 58: 258–262.

Andelt, W. F., T. P. Wooley, and S. N. Hopper. 1997. Effectiveness of barriers, pyrotechnics, flashing lights, and Scarey Man® for deterring heron predation on fish. Wildlife Society Bulletin 25:686–694.

Avery, M. L., and five coauthors. 1995. Aversive conditioning to reduce raven predation on California least tern eggs. Colonial Waterbirds 18:131–138.

Curtis, K. S., W. C. Pitt, and M. R. Conover. 1996. Overview of techniques for reducing bird predation at aquaculture facilities. Utah State University, Jack H. Berryman Institute, Logan.

Mott, D. F., and R. D. Flynt. 1995. Evaluation of an electric fence system for excluding wading birds at catfish ponds. Progressive Fish-Culturist 57:88–90.

Peters, F., and M. Neukirch. 1986. Transmission of some fish pathogenic viruses by the heron, *Ardea cinerea.* Journal of Fish Diseases 9:539–544.

Pitt, W. C., and M. R. Conover. 1996. Predation at intermountain west fish hatcheries. Journal of Wildlife Management 60:616–624.

Rodgers, J. A., Jr. 1982. Food of nestling little blue herons on the west coast of Florida. Florida Field Naturalist 10:25–30.

Rogers, J. R., Jr. 1974. Responses of caged red-winged blackbirds to two types of repellents. Journal of Wildlife Management 38:418–423.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics, 2nd edition. McGraw-Hill, New York.

Stickley, A. R., Jr., D. F. Mott, and J. O. King. 1995. Short-term effectiveness of an inflatable effigy on cormorants at catfish farms. Wildlife Society Bulletin 23:73–77.